

Investigation into Induction of a Feeling of Pleasure Caused by Vibration

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Abstract: The purpose of this research is to investigate the induction of a feeling of pleasure caused by vibration. In this research, feelings were modeled in order to evaluate pleasure-displeasure. As a result, pleasure-constructing axes consisted of active pleasure - passive pleasure. Next, physiological and psychological evaluation experiments were carried out using a rocking chair to evaluate the feeling of pleasure under oscillation stimulation. The rocking chair was chosen for the experiments because it could give long-period vibration with which people feel comparatively comfortable. And, in order to evaluate the feeling of pleasure under controlled vertical vibration stimulation, people were made to sit in an automotive seat attached to a vibration seat. As a result, it was confirmed that the feeling of pleasure such as the passive pleasure and the active pleasure could be induced by vibration, and effective physiological and psychological indexes for evaluating the feeling of pleasure were revealed.

Key words: *Vibration, Feeling, Pleasure, Evaluation, Emotive adjectives.*

1. Introduction

Various means of transport, including trains, automobiles, planes, and ships, have been developed in order to allow people to reach their destinations faster. However, when traveling using these means of transportation, passengers are frequently exposed to vibration and oscillation.

It is known that vibration and oscillation have an influence on the performance of the machine itself as well as psychological and physiological effects on people. At present, people put more emphasis on comfort. Therefore, within the development of means of transport and products that accompany vibration, in order to develop products which will coordinate the relationship between humans and machines and bring a feeling of comfort, it is essential to have a design that considers humans as an element that determines the characteristics of the products under the vibration environment. This is becoming an important task.

Conventional research on human body vibration focuses on evaluation of a degree of unfavorable influence of vibration on a human body, its simulation and prediction of physiological or subjective influence [1, 2, and 3]. Therefore, most of the specialized research focuses only on methods for reducing vibration, with the goal of

reducing the vibration itself. Product development by corporations is based on a similar line of thought, and focuses attention on how to control the vibration.

In contrast, there are currently almost no research examples concerning active use of vibration and oscillation. It is empirically known that vibration gives humans not only a feeling of displeasure, but in effect it can provide a feeling of pleasure if the vibration and the oscillation are of a specific kind. Therefore, the purpose of this research is to examine vibration and oscillation from the perspective of pleasure and to identify the kind of vibration and oscillation that induces a feeling of pleasure, based on physiology, psychology, and physics.

In this research, an evaluation form was prepared by constructing an emotion model through the multidimensional scaling method, using emotive words. An evaluation experiment was conducted on the feeling of pleasure under oscillation stimulation as well as under vibration stimulation that was forcibly applied, and then the feeling of pleasure under oscillation and vibration stimulation was evaluated.

2. "PLEASURE - DISPLEASURE" AND FEELINGS

2.1 A feeling model for evaluating "pleasure - displeasure"

The meaning of words that relate to the sense of "pleasure - displeasure" is ambiguous, making it necessary to define the sense of "pleasure - displeasure" in order to study them from a scientific viewpoint. First, in this research, feelings were modeled using emotion words. Using the multidimensional scaling method, 28 emotion words were plotted within multidimensional space in order to determine the potential structure of feelings.

2.1.1 Similarity evaluation of adjectives that express feelings

In order to model feelings, 28 emotive adjectives were selected from documents relating to psychology [4, 5], and similarity among these emotive adjectives was evaluated on a scale of one to five. The first rating is "very similar", the second rating is "similar", the third rating is "slightly similar", the fourth rating is "dissimilar", and the fifth rating is "completely dissimilar". The evaluation was carried out with three subjects, and an evaluation matrix was constructed based on the results.

2.1.2 A multidimensional space constellation of the emotive adjectives

The multidimensional scaling method was conducted with respect to this evaluation matrix, and the emotive adjectives were arranged within multidimensional space (Fig.1). Fig. 1 is a diagram in which the results obtained through analysis on a three-dimensional scale were projected on a two-dimensional plane. When semantic interpretation of Dimensions 1 and 2 in the thus-obtained constellation diagram of the emotive adjectives was conducted, Dimension 1 was identified as "pleasure - displeasure" and Dimension 2 is "awakening - calming". That is to say, it is possible to consider that the

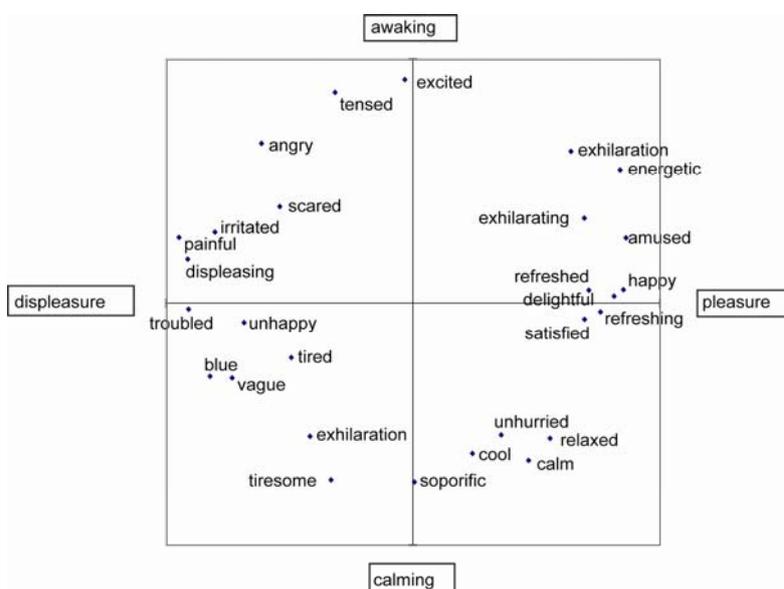


Figure1. Emotive adjectives arranged within multidimensional space

feelings of "pleasure - displeasure" are one of the most significant concepts in human feelings. This result seems to match with the dimension [pleasantness/unpleasantness] proposed by Wilhelm Wundt (1832-1920) who founded his laboratory at the University of Leipzig. And, "awakening - calming" in Fig.1 seems to be close to the other dimension [calm/excitement].

2.2 Classification of

feelings of pleasure by the multidimensional scaling method

In the previous section, it was revealed that the feelings of "pleasure - displeasure" are one of the most significant concepts in human feelings. Therefore, in this section, classification using the multidimensional scaling method was carried out again with a specific focus on the "feelings of pleasure". 23 emotive adjectives that seemed to represent just pleasure feeling were selected from the 28 adjectives defined in Section 2 in order to elucidate more clearly the structure of the "feelings of pleasure". Then, the similarity among these adjectives of the "feelings of pleasure" was evaluated on a four-point scale.

2.2.1 Classification of the adjectives of "feelings of pleasure"

A tree diagram was obtained by applying the multidimensional scaling method to this evaluation matrix and then carrying out cluster analysis with respect to the adjectives of "feelings of pleasure". When the "feelings of pleasure" were classified based on the obtained results, they were classified into the following four groups: "feelings of security", "feelings of excitement", "feelings of satisfaction" and "feelings of refreshment" (Fig.2). Therefore, in this research, evaluation of the feelings of pleasure under oscillation and vibration stimulation was carried out by referring to this classification model of the feelings of pleasure.

2.2.2 A constellation diagram of the feelings of pleasure

A constellation diagram of the feelings of pleasure in which the adjectives of "feelings of pleasure" were arranged within multidimensional space was prepared by the multidimensional scaling method, and axes on a "Dimension 1" - "Dimension 2" plane were interpreted (Fig. 2). It was observed that the active direction of "Dimension 1" is "active pleasure" which operates positively such as "energetic" and "amused", while the negative direction is "passive pleasure" such as "relaxed" and "relieved". It was revealed that the positive direction of "Dimension 2" is "pleasure people feel when displeasure is removed", such as "refreshing" and "refreshed", while the negative direction is "pleasure of satisfaction" such as "happy" and "satisfied". Specifically, it was suggested that the axes constructing "pleasure" are "active pleasure" - "passive pleasure" and "pleasure obtained by removal of displeasure" - "pleasure of satisfaction".

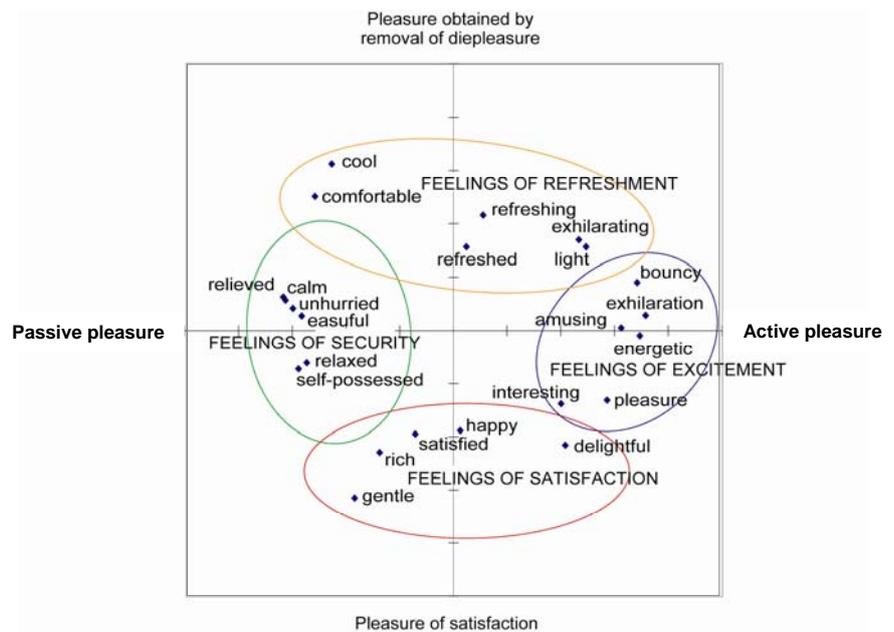


Figure2. Adjectives of "feelings of pleasure" arranged within multidimensional space

3. Evaluation of the Feelings of Pleasure under Oscillation Stimulation

3.1 Oscillation stimulation experiment using a rocking chair

This experiment focused on a rocking chair which people comparatively feel "pleasure" and can control oscillation on their own will, and it aimed to physiologically and psychologically evaluate the feelings of pleasure under oscillation stimulation and reveal oscillation characteristics which induced the feelings of pleasure.

3.1.1 The method of experiment

This experiment used a rocking chair in order to give subjects a long-period of oscillation, which they comparatively feel comfortable and allowed them to grasp the oscillation characteristics by independently controlling the oscillation. The subjects were told the following in advance: "Swing the rocking chair in the way you like. If you feel more comfortable without any oscillation, then you may sit still."

First, subjects spent five-minute resting to have their physiological data measured. Then they were asked to sit in the rocking chair, and physiological data and oscillation data were measured for 10 minutes. In addition, blood pressure was measured and they were made to answer subjective evaluation before and after the experiment. This procedure was conducted in two cases. One case was without a task, while the other was with a task of reading.

3.1.2 Measured data

Indexes which were measured in this experiment are largely classified into a physiological index, a psychological index, and a physical index. The physiological index is obtained by measuring heart rate, blinking activity, brain waves and blood pressure [6, 7]. The psychological index consists of psychological evaluation under the oscillation stimulation and subjective evaluation of oscillation characteristics. The physical index is oscillation characteristics that can be obtained by attaching an acceleration sensor to the rocking chair. Table1 shows a list of the above measurement items, and Fig.3 shows an explanatory diagram.

3.1.3 Subjective evaluation of the feelings of pleasure under the oscillation stimulation

Psychological evaluation during the oscillation stimulation was carried out using eight pairs of adjectives. Evaluation items were decided by referring to the constellation diagram and classification of the feelings of pleasure (Fig.2).

Table1. Measurement items

Physiological indices	
heart rate:	sympathetic and parasympathetic nerve activities
blinking activity:	blinking rate
brain wave:	α band rate
blood pressure:	maximum and minimum blood pressures
Physical index	
acceleration:	on the backrest of the rocking chair
Psychological indices	
psychological evaluation of "feeling of pleasure" under the oscillation stimulation	
subjective evaluation of oscillation characteristics	

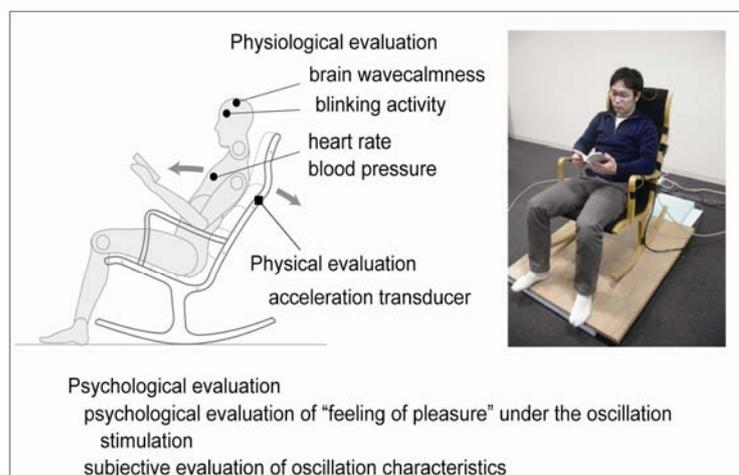


Figure3. Explanatory diagram of measurement items

3.2 Analysis and study of the results of the experiment

3.2.1 Physiological change due to the oscillation stimulation

The physiological indexes of the nine subjects were subjected to a repeated-measures one-way analysis of variance (paired factors) in each case of with or without the task, and verification of difference between the quiet time and the oscillation stimulation time was carried out.

As a result, significant difference was observed in the mean heart rate (with the task). However, it was considered that this physiological change was caused not only by the oscillation stimulation but also by exercise done by the subjects themselves, which led to increase in the mean heart rate.

In addition, although significant difference was not observed, indexes that showed an increasing tendency due to the oscillation stimulation were the mean heart rate and the maximum blood pressure without the task and the sympathetic nerve activity index and the blinking rate with the task. On the contrary, indexes that showed a decreasing tendency were the blinking rate without the task and the parasympathetic nerve activity index with the task.

Based on the whole results, it was considered that, since there were a lot of physiological indexes in which uniform change was not observed due to the oscillation stimulation, the physiological change due to the oscillation stimulation largely depended on individual differences and various factors such as preference to the oscillation and a mood at the time had influence on it.

3.2.2 Psychological change due to the oscillation stimulation

The psychological indexes of the nine subjects were subjected to the one-way analysis of variance through repeated measurement (paired factors) in each case of with or without the task, and verification of difference between the quiet time and the oscillation stimulation time was carried out. As a result of the verification, significant difference was observed in "vague - refreshing"(Fig.4), and the result was that feelings of refreshment increased due to addition of the oscillation stimulation. It was considered that this result was obtained because feelings became active due to the oscillation and thus the feelings of refreshment increased.

Although significant difference was not observed, indexes that showed an increasing tendency were feelings of calmness without the task and feelings of calmness, feelings of satisfaction and feelings of security with the task. However, since there were a few psychological indexes that showed a uniform tendency due to the oscillation stimulation, it was understood that there were big individual differences among the subjects with respect to the oscillation.

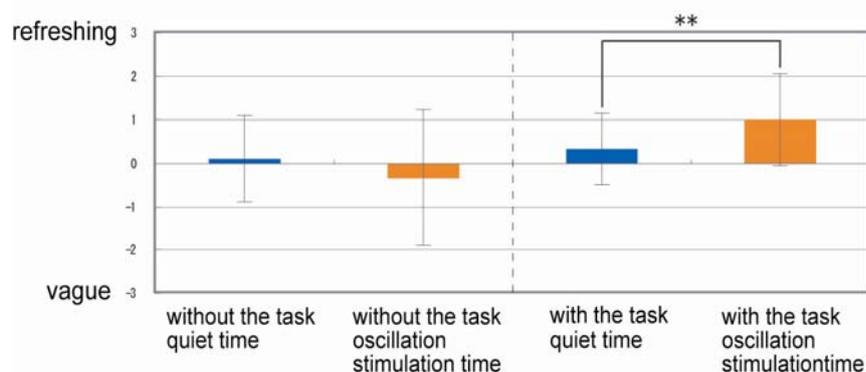


Figure4. Feelings of refreshment increased due to addition of the oscillation stimulation

Table2. Correlation between the physiological indexes and the psychological indexes

(a) without the task

	sympathetic nerve activity	parasympathetic nerve activity	heart rate	α band rate	β band rate	blinking rate	maximum blood pressure	minimum blood pressure
restless - self-possessed	0.15	-0.18	-0.10	0.21	-0.20	-0.30	0.69	-0.18
unsatisfied - satisfied	-0.23	0.06	0.06	0.45	-0.43	-0.33	0.66	-0.06
hard - pleasure	0.11	-0.16	0.23	0.11	-0.13	-0.15	0.70	-0.04
lifeless - exhilaration	0.33	-0.46	0.28	-0.21	0.16	0.06	0.72	-0.08
uneasy - relieved	-0.12	-0.01	0.25	0.39	-0.35	-0.20	0.67	-0.14
vague - refreshing	0.19	-0.41	0.54	-0.30	0.19	0.43	0.47	-0.08
displeasure - pleasure	-0.62	0.48	-0.32	0.74	-0.75	-0.65	0.65	-0.45
quiet - awakening	0.24	-0.10	0.17	-0.33	0.34	0.08	0.39	-0.47

(b) with the task

	sympathetic nerve activity	parasympathetic nerve activity	heart rate	α band rate	β band rate	blinking rate	maximum blood pressure	minimum blood pressure
restless - self-possessed	0.46	-0.42	-0.12	-0.52	0.49	0.23	0.45	0.21
unsatisfied - satisfied	-0.33	0.32	-0.41	0.11	-0.05	-0.66	-0.14	0.40
hard - pleasure	0.01	-0.16	-0.44	0.10	-0.02	-0.72	0.22	-0.13
lifeless - exhilaration	-0.44	0.44	-0.16	0.10	0.17	-0.59	0.12	0.40
uneasy - relieved	0.35	-0.21	0.22	-0.24	0.08	0.55	0.04	0.48
vague - refreshing	-0.80	0.69	0.42	0.45	-0.24	0.26	-0.17	-0.19
displeasure - pleasure	-0.30	0.22	-0.53	-0.27	0.37	-0.67	0.28	0.14
quiet - awakening	-0.10	0.09	0.83	0.16	-0.03	0.65	0.19	0.25

3.3 Analysis of correlation between psychological reaction and physiological reaction

A relationship between physiological reaction and psychological reaction among each evaluation index was studied using a simple correlation coefficient. The amount of change in the psychological indexes and the rate of change in the physiological indexes from the quiet time due to the oscillation stimulation were used as data. Table2 (a) shows the results of the correlation analysis without the task, and Table2 (b) shows the results with the task.

In this experiment, since the sample number n (the number of subjects) is 9, when the significance level α is 0.05, the critical value of the Pearson's product-moment correlation coefficient is 0.66. That is to say, when the correlation coefficient is 0.66 or more or -0.66 or less, the significance level is 0.05 and thus it can be decided that there is correlation.

3.3.1 Without the task

As a result of the correlation analysis, the physiological indexes that were found to have significant correlation with the psychological indexes were the wave α band rate, the wave β band rate and the maximum blood pressure. Among them, it was clarified that the maximum blood pressure was positively correlated with five indexes of "feelings of calmness", "feelings of satisfaction", "amusement", "exhilaration" and "feelings of

security". In addition, it was understood that the wave α band rate was positively correlated with the feelings of "pleasure - displeasure" and the wave β band rate was negatively correlated with them.

Based on these findings, it was determined that the maximum blood pressure was one of the important indexes in the evaluation under the oscillation stimulation without the task.

3.3.2 With the task

As a result of the correlation analysis, the physiological indexes that were found to have significant correlation with the psychological indexes were four indexes of the sympathetic nerve activity index, the parasympathetic nerve activity index, the mean heart rate and the blinking rate. Among them, it was revealed that the blinking rate was negatively correlated with "feelings of satisfaction", "amusement" and "feelings of pleasure - displeasure". In other words, as the "feelings of satisfaction", the "amusement" and the "feelings of pleasure - displeasure" increased, the blinking rate decreased.

Based on these findings, it was determined that the blinking rate was one of the important indexes in the evaluation under the oscillation stimulation with the task.

4. Evaluation Experiment on the Feelings of Pleasure under Vertical Vibration

Stimulation

The purpose of this experiment was to verify whether the "blood pressure" which was the effective index in the experiment using the rocking chair was an effective index also in evaluation of the feelings of pleasure under controlled vertical vibration environment, and to find out vertical vibration stimulation that induces the feelings of pleasure.

4.1 The method of experiment

This experiment was carried out by focusing on frequency of vibration. The vibration was generated using a uniaxial vibration exciter (Deltatooling Co., Ltd. Fig.5).

- i) Subjects: Eleven healthy undergraduate and graduate students (Men: 7, Women: 4, mean age: 23 years).
- ii) Vibration conditions: Frequency was 0 - 10 Hz, and acceleration was 0.1 G (uniform). The subjects were made to sit in car seats and then were asked to seek for the vibration that they perceived as "pleasant" by continuously changing the frequency. The frequency of 0 - 10 Hz was divided into four groups of 0 - 1 Hz, 1 - 3 Hz, 3 - 6 Hz and 6 - 10 Hz, and the experiment was carried out by repeating quiet time and vibration stimulation.
- iii) Experimental procedure: The subjects were informed that the "pleasure" in this experiment included the passive pleasure such as relaxation and the active pleasure such as amusement. On that basis, vibration

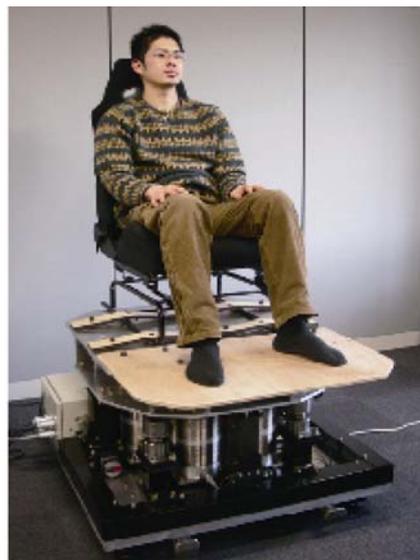


Figure5. Uniaxial vibrator exciter

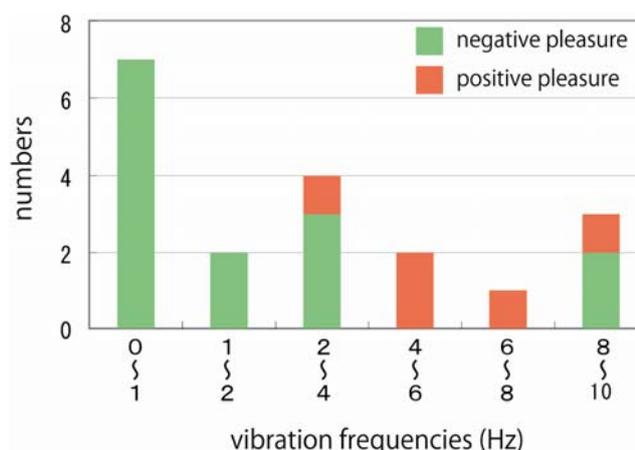


Figure6. Frequencies regarded as "pleasant"

stimulation which was regarded as the "pleasure" was given to the subjects for three minutes, and measurement of blood pressure and psychological evaluation were carried out before and after it.

iv) Measurement items: Physiological indexes were the maximum and minimal blood pressure which was one of the effective indexes in the voluntary oscillation stimulation experiment. Psychological indexes were psychological evaluation and subjective evaluation of the vibration similarly to the experiment using the rocking chair.

4.2 Analysis and study of the results of the experiment

Physiological reaction and psychological reaction differ between the "passive pleasure" such as relaxation and the "active pleasure" such as amusement. Therefore, evaluation was carried out by classifying the "pleasure" into the "passive pleasure" and the "active pleasure".

4.2.1 Frequencies regarded as "Pleasant"

Some subjects felt the "pleasure" in more than one frequency, and three frequencies were regarded as "pleasant" at the most. Fig.6 shows the frequencies regarded as "pleasant".

As a result of the experiment, the "passive pleasure" was felt in low-frequency of 0 - 3 Hz and comparatively high-frequency of 8 - 10 Hz. Small vibration in 0 - 1 Hz was regarded as the "passive pleasure" in many cases. The "active pleasure" was felt in vibration of 3 - 9 Hz, which strongly shook the body. In addition, the subjects felt that the "active pleasure" was as if they had been "riding in a car" or "riding in an attraction".

4.2.2 Psychological change due to the vibration stimulation

Verification of psychological change before and after the stimulation was carried out through the one-way analysis of variance by repeated measurement (paired factors) (Table3). As a result, it was revealed that, due to the "passive pleasure" stimulation, the "feelings of calmness", the "feelings of security", the "feelings of satisfaction" and the "pleasure" of the subjects were induced but the "feelings of awakening" decreased. Concerning the physiological indexes of "maximum and minimal blood pressure", uniform change was not confirmed.

It was understood that, due to the "active pleasure" stimulation, the "amusement", the "exhilaration", the "feelings of refreshment", the "feelings of satisfaction" and the "pleasure" of the subjects were induced. Comparing the case with the "passive pleasure" stimulation, although the "feelings of satisfaction" and the "pleasure" were observed in both, the "exhilaration" and the "feelings of refreshment" showed the obvious difference. Concerning the physiological indexes of "maximum and minimal blood pressure", uniform change was not confirmed.

4.2.3 Analysis of correlation between the psychological reaction and the physiological reaction

Correlation between the amount of psychological change and the rate of physiological change due to the vibration stimulation was revealed through correlation analysis.

In the case of the "passive pleasure" stimulation, the maximum blood pressure showed clear negative correlation to the "feelings of satisfaction" and the "feelings of security" ($p < 0.05$). The minimal blood pressure showed negative correlation to the "feelings of calmness" and the "feelings of satisfaction" while it showed positive correlation to the "exhilaration" and the "feelings of awakening" ($p < 0.05$). Generally, it is said that as the "feelings of calmness" and the "feelings of security" increase, blood pressure decreases. A similar tendency was also confirmed in the "passive pleasure" stimulation in this experiment.

Table3. Correlation between the amount of psychological changes and the rate of physiological change due to the vibration stimulation

(a) "negative pleasure" stimulation

	calmness	satisfaction	amusement	exhilaration	security	refreshment	pleasure	awakening
maximum blood	-0.469	-0.575	0.008	0.401	-0.553	0.057	-0.310	0.338
minimum blood	-0.591	-0.536	0.414	0.654	-0.246	0.042	-0.211	0.611

(b) "positive pleasure" stimulation

	calmness	satisfaction	amusement	exhilaration	security	refreshment	pleasure	awakening
maximum blood	0.169	0.045	0.635	0.158	0.371	0.100	0.516	0.201
minimum blood	0.347	0.556	0.741	0.479	0.842	0.488	0.912	-0.007

 p<0.01  p<0.05

In the case of the "active pleasure" stimulation, the minimal blood pressure showed clear positive correlation to the "feelings of security" ($p < 0.05$) and the "pleasure" ($p < 0.01$). When the "passive pleasure" stimulation and the "active pleasure" stimulation were compared with each other, it was revealed that a tendency of the correlation became the opposite in the "feelings of calmness", the "feelings of satisfaction" and the "pleasure".

5. Conclusion

The present experiment was conducted in order to study the induction of pleasure due to vibration. As a result, it was shown that both "passive pleasure" and "active pleasure" were induced by vibration. In addition, the sense of "passive pleasure" or "active pleasure" was influenced by the vibration frequency, and passive pleasure was induced at 0 - 3 Hz and 8 - 10 Hz, while active pleasure was induced at 3 - 9 Hz. From a physiological perspective, it was revealed that the blinking rate, parasympathetic nerve activity, and minimal blood pressure were important indexes in the evaluation under the oscillation stimulation. In particular, it was confirmed that "blood pressure" was one of the effective indexes in the evaluation under the "passive pleasure" stimulation. These findings suggest that vibration could be regarded as a "factor of pleasure" in vibration environments where the accumulative effects of the duration of exposure to vibration were considered to be subtle.

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